AV '23 CONFERENCE ASPHALT PAVEMENTS 2023

Status quo of the use of rejuvenators, a German perspective

Sebastian Miesem

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Motto: Let´s asphalt out of the crisis

Proof of the effectiveness of a Rejuvenator according to the H Re WA (edition 2022) of the FGSV

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General

- In terms of sustainability and the circular economy, the reuse of asphalt and the recovery of reclaimed asphalt as a resource is becoming more and more important.
- The addition of reclaimed asphalt in asphalt production leads to changes in the resulting properties of the asphalt
- To compensate for this ageing process rejuvenators can be used to achieve the returned similar properties to its original rheological state.
- “Guidelines for the application of rejuvenators in the reuse of asphalt” (H Re WA) in 2022 by the Forschungsgesellschaft (FGSV)

Definitions

- Rejuvenators based on renewable raw materials, mineral-based rejuvenators. Bitumen with a lower viscosity can also be used.
- Rejuvenator is an additive that restores an aged bitumen to near its original rheological properties.
- Rejuvenated bitumen is a bituminous binder consisting of aged bitumen that has been restored to near its original rheological properties by the addition of a rejuvenator.
- Bitumen ageing is the change over time of bitumen properties relevant to processing and use.

Proof of the rejuvenator at bitumen: Level B

- Testing as-delivered condition
- Aged Bitumen
- Determination of the rejuvenator addion amount
- Testing of the rejuvenated bitumen
- Testing of aged rejuvenated bitumen
- Complation of the results and assignment of the rejuvenator

Proof of rejuvenator at asphalt: Level A

- Determination of the asphalt properties of the reference asphalt mix
- Testing of the asphalt mixture conditioned according to the Brunswick ageing procedure (BSA)
- Determination of the Rejuvenator addition amount
- Determination of the asphalt properties of the rejuvenated asphalt mix
- Testing of the rejuvenated asphalt mix conditioned according to the Brunswick ageing procedure (BSA)

Compilation of the results of the bitumen level of the rejuvenator RheoFalt® HP-AM

Level	Test result Addition = 7.0 wt.%				Classification according to the classification criteria of the Table 1 of H Re WA 2022			
	T (G* = 15 kPa)	δ (G* = 15 kPa)	T (S = 300 MPa)	T (m = 0,3)	T (G* = 15 kPa)	δ (G* = 15 kPa)	T (S = 300 MPa)	T (m = 0,3)
	[°C]	[°]	[°C]	[°C]	[°C]	[°]	[°C]	[°C]
B0	**52,0**	**83,0**	**-18,6**	**-18,4**	-	-	-	-
B1.1	**58,8**	**80,2**	NR	NR	-	-	-	-
B1.2	**73,3**	**74,7**	**-16,0**	**-10,0**	-	-	-	-
B2a	**50,5**	**79,7**	NR	NR	-	-	-	-
B2b *(optional)*	**53,0**	**79,2**	NR	NR	-	-	-	-
B2c *(optional)*	**52,6**	**79,0**	NR	NR	-	-	-	-
B3	**52,6**	**79,0**	**-20,4**	**-17,6**	**ER/MR**	**~~ER/MR~~**	**ER/MR**	**ER/MR**
B4.1	**58,5**	**77,0**	NR	NR	**ER/MR**	**~~MR~~**	-	-
B4.2	**74,7**	**69,8**	**-18,8**	**-8,6**	**ER/MR**	**~~MR~~**	**ER/MR**	**ER/MR**

ER: Simple Rejuvenator
MR: Multiple Rejuvenator
NR: No Requirement

Assignment of the test parameters

Level	Test parameters	Result designation
A0	A0E1.1	Equi-shear modulus temperature T(G* = 15 kPa) on recovered road bitumen
	A0E1.2	Phase angle δ(G* = 15 kPa) on recovered road bitumen
	A0E2	Ratio value of the splitting tensile strengths ITSR
	A0E3	Fractional temperature T_F
	A0E4.1	Tensile strength β_t (T = 20 °C)
	A0E4.2	Tensile strength β_t (T = 5 °C)
	A0E4.3	Tensile strength β_t (T = -10 °C)
	A0E4.4	Tensile strength β_t (T = -25 °C)
	A0E5.1	Fatigue load cycle number N at 0.05 ‰ (T = 20 °C)
	A0E5.2	Fatigue load cycle number N at 0.1 ‰ (T = 20 °C)
	A0E6.1	Elongation rateε (T = 50 °C)

Assignment of the test parameters

Level	Result designation	Result value	Unit	H Re WA 2022
A0	A0E1.1	**52,8**	°C	-
	A0E1.2	**81,0**	°	-
	A0E2	**97,6**	%	-
	A0E3	**-26,1**	°C	-
	A0E4.1	**0,973**	MPa	-
	A0E4.2	**3,814**	MPa	-
	A0E4.3	**5,927**	MPa	-
	A0E4.4	**3,815**	MPa	-
	A0E5.1	**496.552**	-	-
	A0E5.2	**34.302**	-	-
	A0E6.1	**0,8**	‰ · 10^{-4}	-

Assignment of the test parameters

Level	Test parameters	Result designation
A1	A1E1.1	Equi-shear modulus temperature T(G* = 15 kPa) on recovered road bitumen
	A1E1.2	Phase angle δ(G* = 15 kPa) on recovered road bitumen

Level	Result designation	Result value	Unit	Performance requirement according to table 4 of the H Re WA 2022	
A1	A1E1.1	**72,7**	°C	**A1E1.1 ≥ 52.8 °C + 15.0 °C** **A1E1.1 ≤ 52.8 °C + 20.0 °C**	✓
	A1E1.2	**73,8**	°	-	

Assignment of the test parameters

Level	Test parameters	Result designation
A2	A2E1.1	Equi-shear modulus temperature T(G* = 15 kPa) on recovered road bitumen
	A2E1.2	Phase angle δ(G* = 15 kPa) on recovered road bitumen
	A2E2.1	Equi-shear modulus temperature T(G* = 15 kPa) on recovered road bitumen
	A2E2.2	Phase angle δ(G* = 15 kPa) on recovered road bitumen
	A2E3.1	Equi-shear modulus temperature T(G* = 15 kPa) on recovered road bitumen
	A2E3.2	Phase angle δ(G* = 15 kPa) on recovered road bitumen

Assignment of the test parameters

Level	Result designation	Result value	Unit	Performance requirement according to table 4 of the H Re WA 2022
A2	A2E1.1 **(addition 7.0 wt.%)**	**55,9**	°C	-
	A2E1.2 **(addition 7.0 wt.%)**	**78,4**	°	-
	A2E2.1 **(addition 8.5 wt.%)**	**54,1**	°C	-
	A2E2.2 **(addition 8.5 wt.%)**	**78,7**	°	-
	A2E3.1 **(addition 9.0 wt.%)**	**53,8**	°C	-
	A2E3.2 **(addition 9.0 wt.%)**	**78,7**	°	-

Assignment of the test parameters

Level	Test parameters	Result designation
A3	A3E1.1	Equi-shear modulus temperature T(G* = 15 kPa) on recovered road bitumen
	A3E1.2	Phase angle δ(G* = 15 kPa) on recovered road bitumen
	A3E2	Ratio value of the splitting tensile strengths ITSR
	A3E3	Fractional temperature T_F
	A3E4.1	Tensile strength β_t (T = 20 °C)
	A3E4.2	Tensile strength β_t (T = 5 °C)
	A3E4.3	Tensile strength β_t (T = -10 °C)
	A3E4.4	Tensile strength β_t (T = -25 °C)
	A3E5.1	Fatigue load cycle number N at 0.05 ‰ (T = 20 °C)
	A3E5.2	Fatigue load cycle number N at 0.1 ‰ (T = 20 °C)
	A3E6.1	Elongation rateε (T = 50 °C)

Assignment of the test parameters

Level	Result designation (Addition quantity 9.0 wt.-%)	Result value	Unit	H Re WA 2022	
A3	A3E1.1	**55,8**	°C	**52.8 °C ± 3.0 °C**	✓
	A3E1.2	**77,1**	°	-	
	A3E2	**96,8**	%	**≥ 0,85 · 97,6 %**	✓
	A3E3	**-26,1**	°C	**≤ -26.1 °C + 2.0 °C**	✓
	A3E4.1	**1,159**	MPa	**≥ 0.85 · 0.973 MPa**	✓
	A3E4.2	**3,729**	MPa	**≥ 0.85 · 3.814 MPa**	✓
	A3E4.3	**5,107**	MPa	**≥ 0.85 · 5.927 MPa**	✓
	A3E4.4	**3,482**	MPa	**≥ 0.85 · 3.815 MPa**	✓
	A3E5.1	**449.840**	-	**≥ 0,85 · 496.552**	✓
	A3E5.2	**36.651**	-	**≥ 0,85 · 34.302**	✓
	A3E6.1	**0,4**	‰ · 10^{-4}	**≤ 1,15 · 0,8 ‰ · 10^{-4}**	✓

Assignment of the test parameters

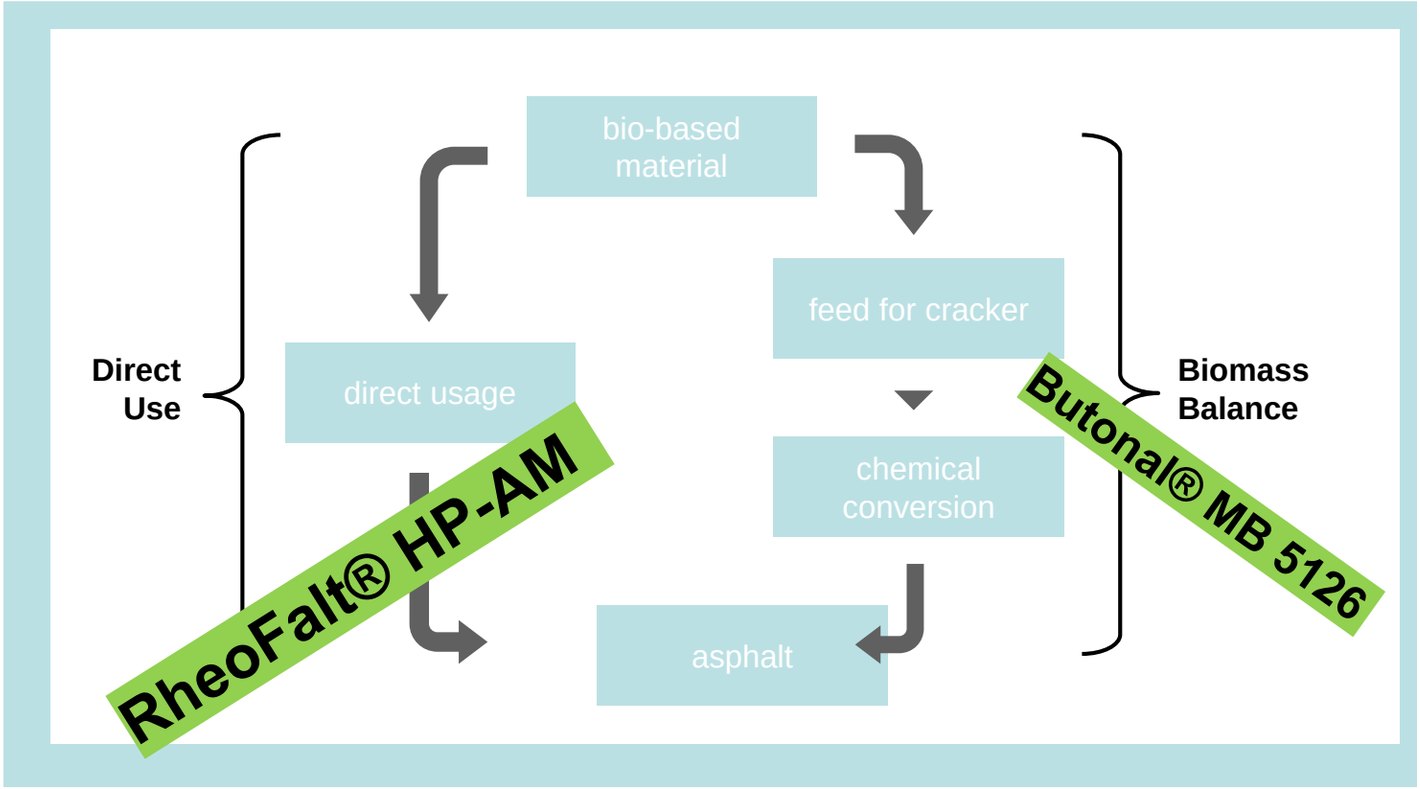
Level	Test parameters	Result designation
A4	A4E1.1	Equi-shear modulus temperature T(G* = 15 kPa) on recovered road bitumen
	A4E1.2	Phase angle δ(G* = 15 kPa) on recovered road bitumen

Level	Result designation	Result value	Unit	H Re WA 2022	
A4	A4E1.1	**75,2**	°C	**72.7 °C ± 3.0 °C**	✓
	A4E1.2	**69,2**	°	-	

Summary part 1

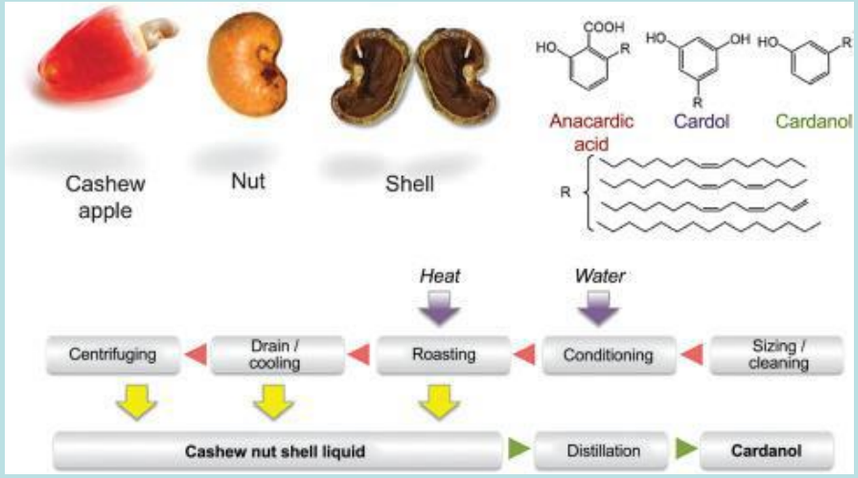
- **The rejuvenator RheoFalt HP-AM fulfils all classification criteria and requirements of rejuvenators.**
- **At the asphalt level all requirements for the asphalt properties could be fulfilled.**
- **Proof of the effectiveness of the rejuvenator RheoFalt® HP-AM both at bitumen level and at asphalt level in accordance with H Re WA (2022 edition) has been provided.**
- **It was even possible to determine improvements compared to the non-aged reference variant:**
  - Improved fatigue behaviour in the fatuige test

Sustainability by bio-based materials



Chemistry based solutions on the biomass balance approach bring a broad and sustainable variety of possible additives for higher asphalt performance.

Cashew nuts – delivery reliability



Region	2021 production [kt]
Ivory Coast	838
India	738
Vietnam	349
Philippines	256
Tanzania	211
World	**3,708**

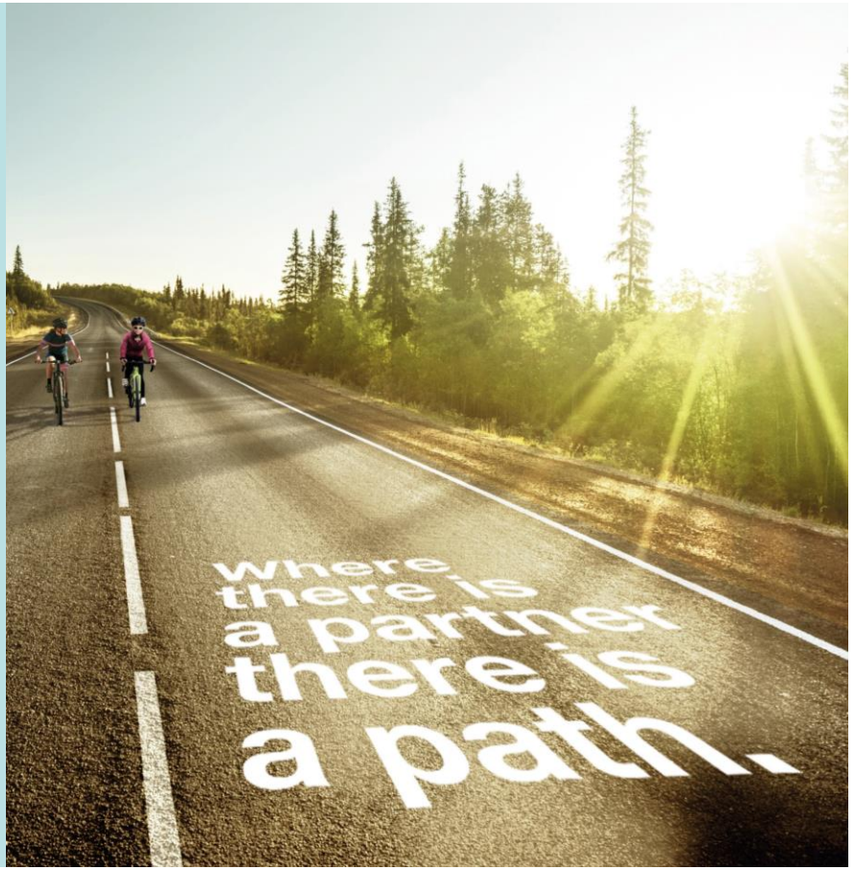
Source: *"Cashew production in 2021; pick lists from world regions/production quantity". FAOSTAT of the UN. 2023. Retrieved 29 April 2023.*

Rheofalt® HP-AM

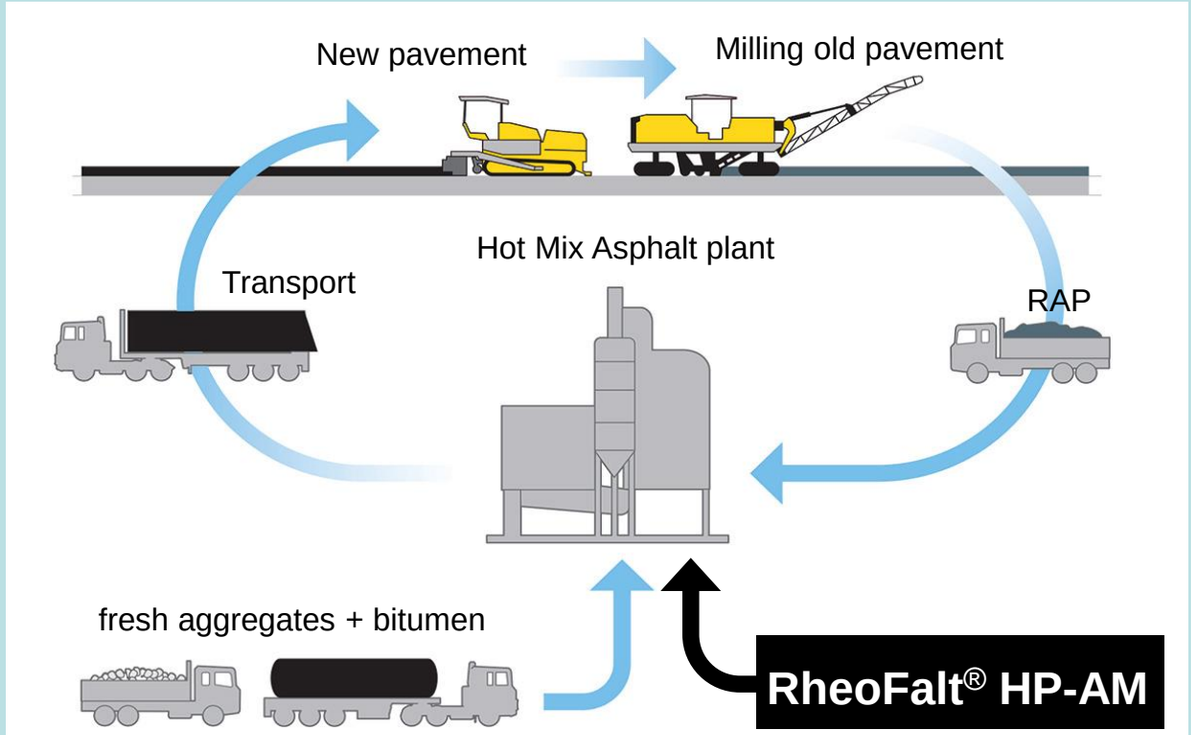
- 100% natural resin based
- 100% renewable
- directly polymerized (patented)
- solvent free / flux-oil free
- vegetable oil free (plasticizer free)

Physical properties

Visible condition	liquid
Viscosity	max. 4000 mPa*s (at 25°C)
Specific gravity	0.97 - 0.99 g/cm³ (at 25°C)
Flash Point	min. 200°C
pH	min. 6



Reclaimed Asphalt Pavement (RAP)



Highest possible reuse

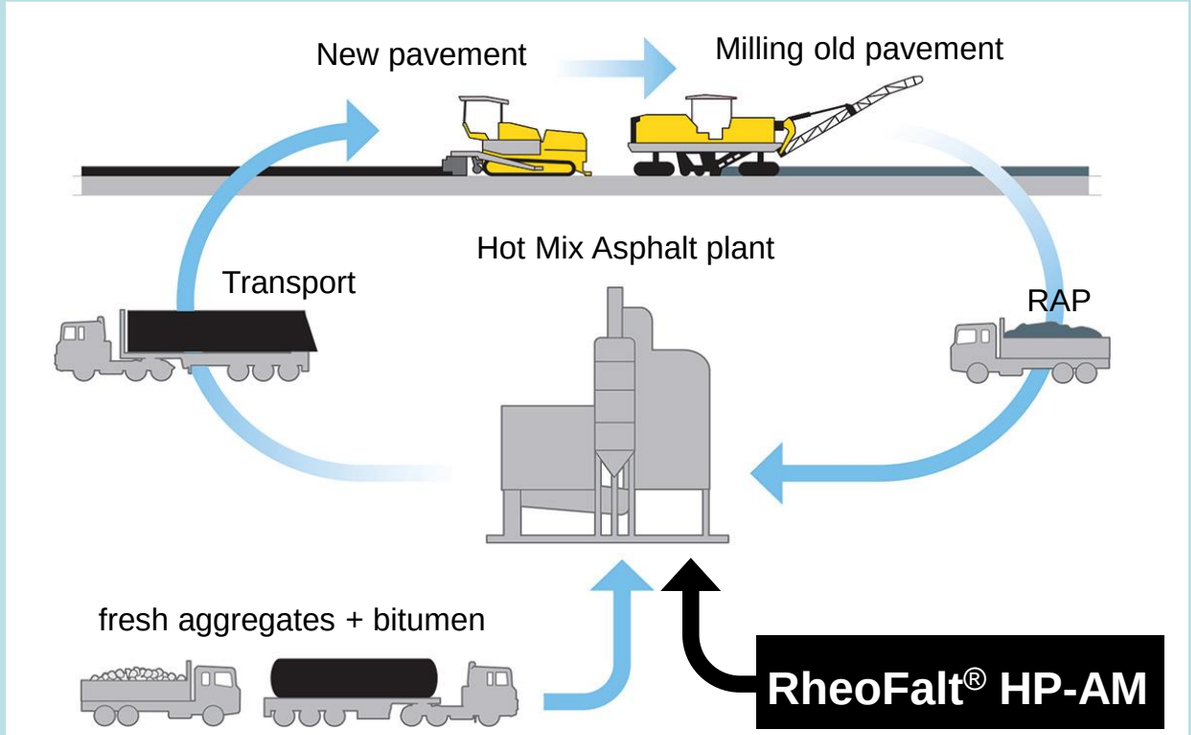
Selective milling

- Fine RAP in surface course
- Medium RAP in binder layer
- Rough RAP in base layer

Valuable raw materials

- Bitumen
- High quality aggregates

Reclaimed Asphalt Pavement (RAP)



Less CO_2 emmisions

- **Less transport**
- **Less raw materials**
  - Bitumen
  - Aggregates

LESS COSTS

High sustainability!

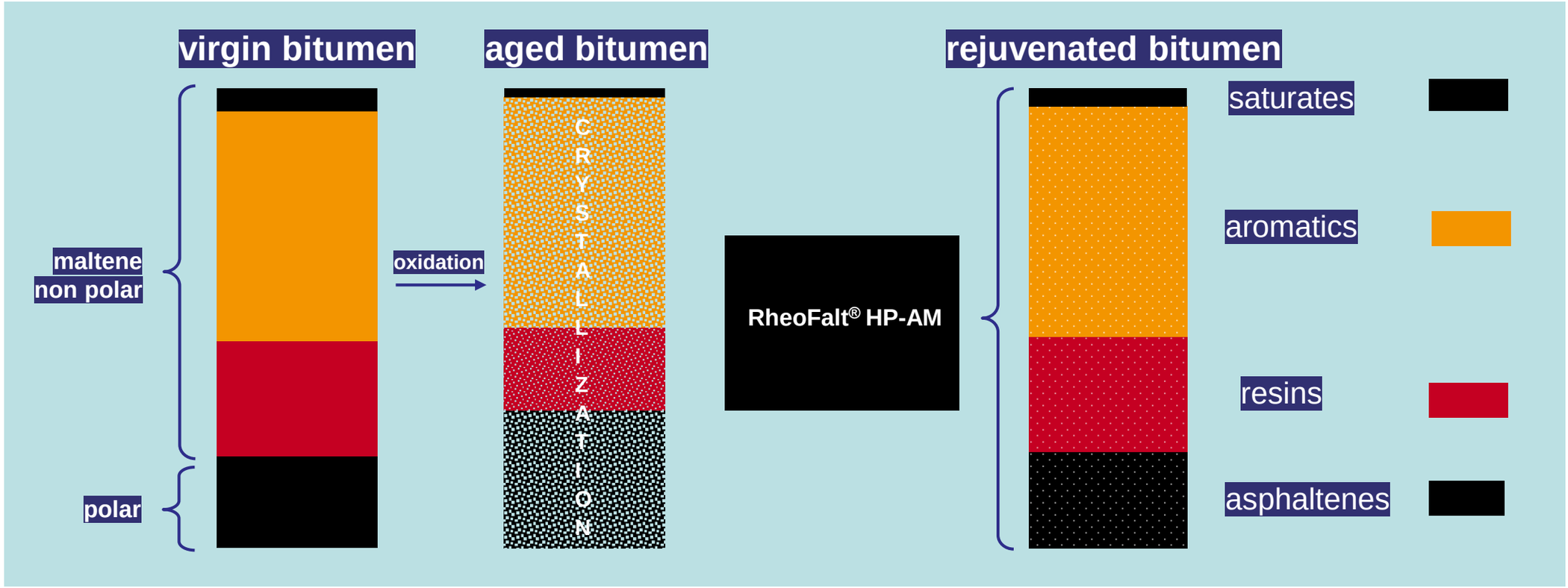
Use in process: RheoFalt® HP-AM

Quelle: BENNINGHOVEN

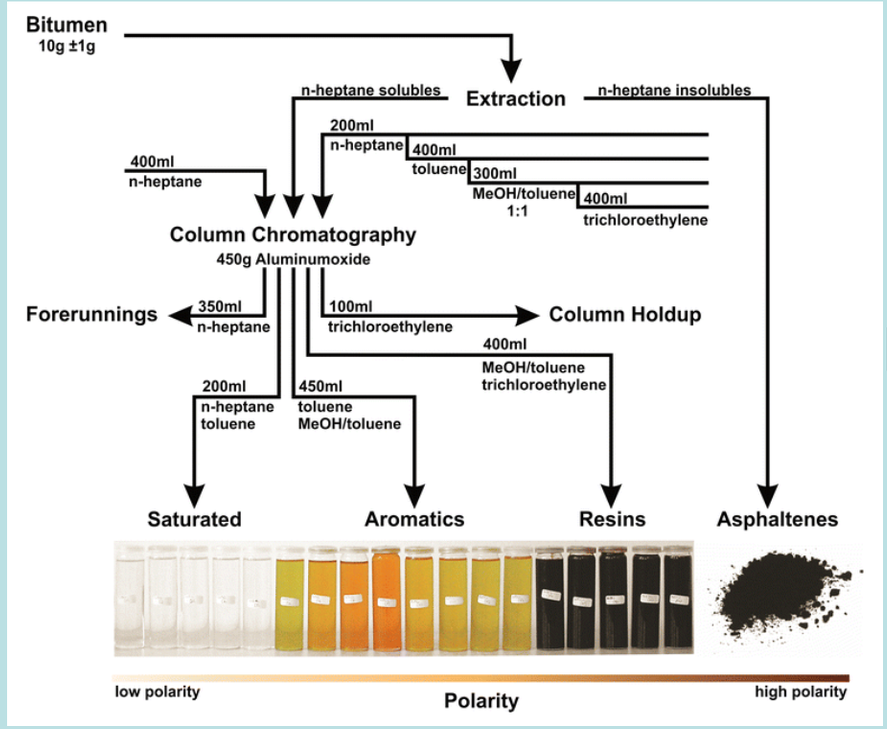
RheoFalt® HP-AM can be added very flexibly at Hot Mix Asphalt plants

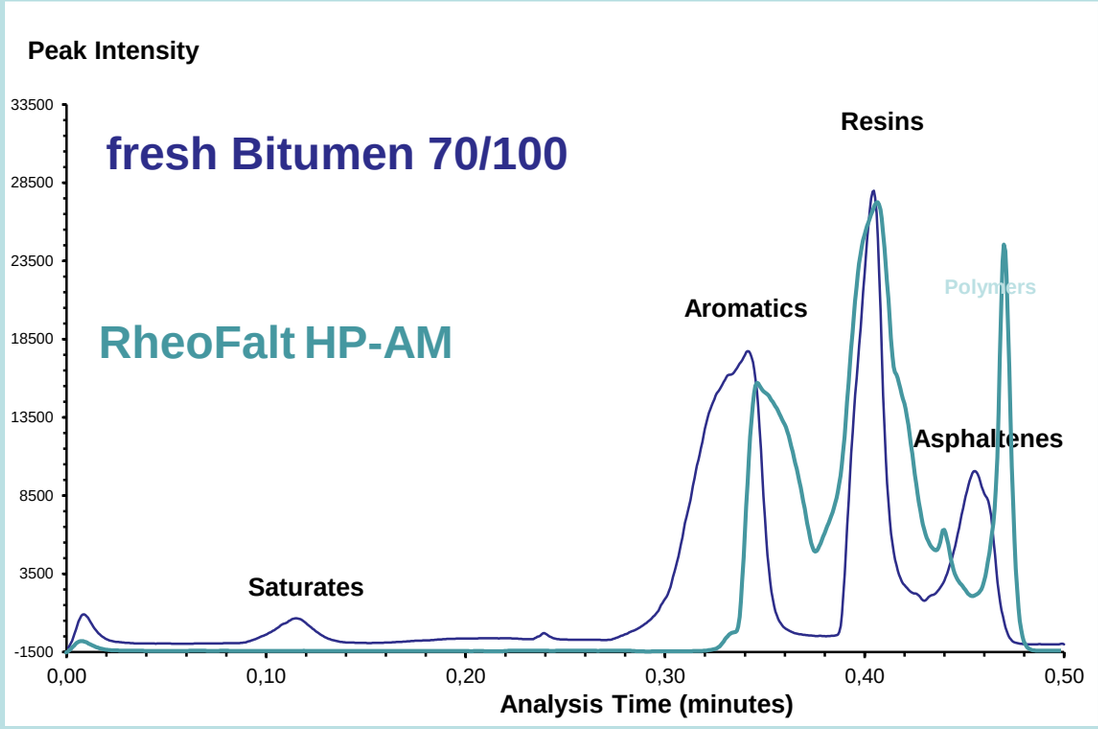
- directly in the mixer
- with binder in bitumen weight
- as pre-blend in bitumen tank
- sprayed over heated RAP

Ageing of bitumen and the effects of RheoFalt® HP-AM



RheoFalt® HP-AM – maltene donor
SARA analysis Iatroscan Chromatogram RheoFalt® HP-AM





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RheoFalt® HP-AM - functions

- Rejuvenator
- Pen corrector
- Adhesion promoter
- Maltene donor

Other applications:

bitumen based roofing systems and bitumen based waterproofing systems

RheoFalt® HP-AM – pen corrector

	RheoFalt®	Hard or aged bitumen mix		
		Bitumen A	Bitumen B	
Penetration [mm/10]		60	0	
$SP_{r\&b}$ [°C]		50,0	0,0	
wt.-% *on* bitumen mix	2,50	100,0	0,0	(Bitumen A + Bitumen B = 100%)

Results for final bitumem mix with RheoFalt

wt.-% *in* bitumen mix	RheoFalt	Bitumen A	Bitumen B
	2,44%	97,56%	0,00%

resulting Penetration	**80 mm/10**
resulting $SP_{r\&b}$	**45,1 °C**

Experimental and has yet to be validated using real data

- **Initial bitumen is 50/70**
- **Addition of 2.5% Rheofalt**
- **Resulting bitumen is 70/100**

Cost savings – RheoFalt® HP-AM

- Less new raw materials
  - bitumen
  - aggregates
- Less transportation
- Less costs

- Long time stability
  - interaction between Rheofalt HP-AM and asphaltenes
  - no migration in final asphalt
  - no micro-aging

Summary part 2

- RheoFalt® HP-AM meets all requirements.
- RheoFalt® HP-AM is a bio-based material.
- RheoFalt® HP-AM is multifunctional.
- RheoFalt® HP-AM as cost saving tool.
- Available!

Sebastian Miesem
Senior Technical Marketing Manager
Mobile: +49 1520 9374196, Email: sebastian.miesem@basf.com
BASF SE, E-EDE/BR, Carl-Bosch-Strasse 38, 67056 Ludwigshafen am Rhein, Germany